

## Beamline 5.3.2 for polymer science scanning x-ray microscopy

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### INTRODUCTION

A new zone-plate focussing Scanning Transmission X-ray Microscope (STXM) will be built at the Advanced Light Source (ALS). It will be dedicated to the study of organic polymers by NEXAFS spectro-microscopy at the K-edges of carbon, nitrogen and oxygen. A bend magnet at the Advanced Light Source is sufficiently bright to illuminate a scanning transmission x-ray microscope, with a zone plate lens to focus the soft x-ray beam at the diffraction limit. Beam line 5.3.2 has been carefully optimized for this one purpose and is designed to achieve count-rates of the order of 1MHz in the microscope<sup>1</sup>. The nominal resolving power is 2000 from 150eV to 600eV using a single spherical diffraction grating. Twice the resolving power is available at reduced flux, and the intensity can be traded independently against the spatial and spectral resolution.

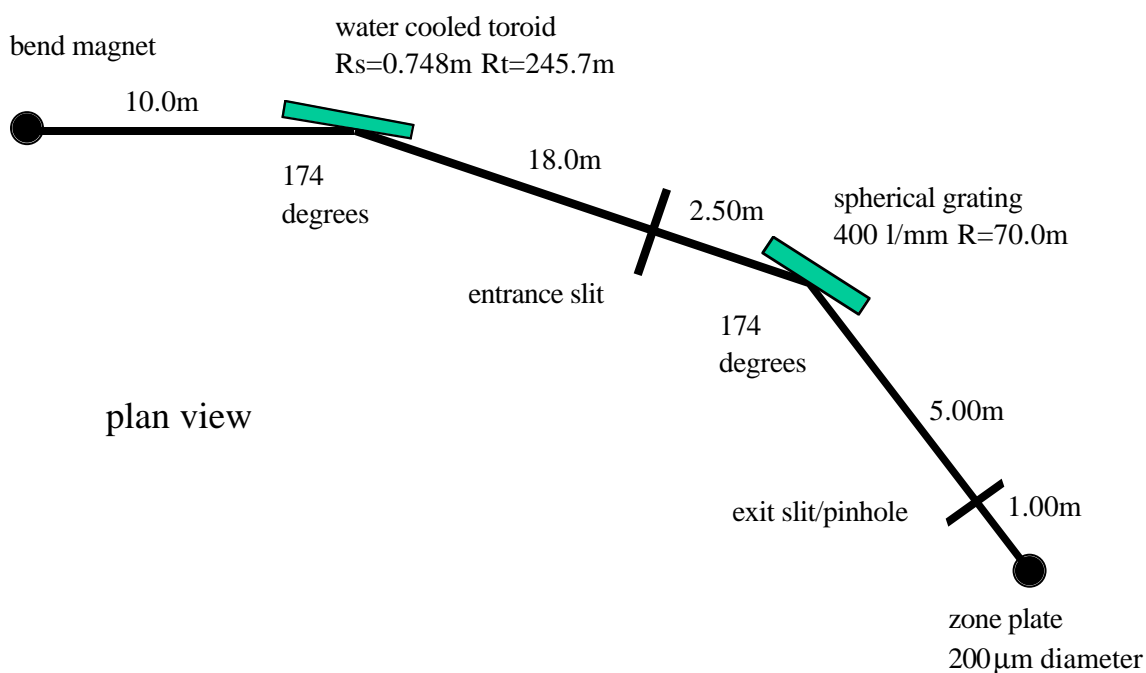


Figure 1. Beam line layout.

### BEAM LINE DESIGN RATIONALE

The zone plate microscope, at its diffraction limit, accepts only the coherent fraction of the illumination. This leads to a beam line design that is almost paraxial. Photons outside the microscope phase space acceptance are lost on slits and by overfilling the zone plate. Because the angular acceptance of the microscope is low, the aberrations of a simple spherical grating monochromator (SGM) are negligible. Even the defocus energy spread can be made acceptably small across the required energy range. The slits need not translate.

The deflection angles are set to give good reflectivity from the nickel optical surfaces. The monochromator magnification is about unity. The grating line density is to be coarse for high efficiency.

A horizontally dispersing monochromator with an entrance slit<sup>2</sup> is adopted to take advantage of the larger horizontal photon phase space filled by the source. The source is imaged horizontally onto the monochromator entrance slit by the first mirror and the beam line design offers a trade-off between flux and spectral resolution, primarily by choice of the entrance slit width. The width of this slit is overfilled by a factor of about ten at the nominal spectral resolution and the slit can be opened or closed to make the trade-off without affecting the experiment otherwise.

The monochromator entrance slit (width  $s_1$ ) illuminates the grating coherently with light diverging through an angle of the order:

$$\lambda / s_1$$

The grating magnification changes the wave front to converge through an angle:

$$\lambda / s_2$$

where  $s_2$  is the width of the image of the entrance slit formed by the grating;  $s_2$  is the matched exit slit width. Implementing  $s_2$  for the exit slit, a zone plate with diameter  $D$  might be placed a distance downstream equal to:

$$D \cdot s_2 / \lambda$$

The zone plate geometrical demagnification is then approximately  $\delta r_N / s_2$ , which matches the diffraction limited zone plate spot size.

Instead of this matched situation the nominal exit slit will be three times narrower. For example, at 300eV a 60 $\mu$ m entrance slit gives  $R=2000$  and the grating magnification is 1.0. The nominal exit slit width is 20 $\mu$ m and it will be overfilled in the dispersive direction with monochromatic light. This means it can be opened without degrading the spectral resolution. There is no intensity penalty incurred at the nominal width. Because the slit is smaller, less microscope magnification is required and the zone plate can be positioned closer to the slits, collecting more light. This beam line design assumes a 200 $\mu$ m diameter zone plate 1m downstream from the exit slit. The nominal exit slit size is equivalent to the diffraction limited spot size of this zone plate arrangement.

The monochromator is sized to allow overfilling of entrance and exit slits at their nominal width. The exit slit is a square aperture with the same width in the dispersive (horizontal) and the non-dispersive (vertical) direction. A critical point is to match the vertical phase space. The ALS vertical source size is particularly small. A magnified vertical image of the source is formed on the exit slit by the first mirror. This is just big enough for the required overfilling. When the exit slit is opened (horizontally and vertically) to trade spatial resolution for flux it will not be overfilled in the vertical direction.

Ray tracing has been performed<sup>3</sup> to verify that the toroid aberrations are negligible, and to provide a visual indication of the degree of overfilling of the entrance and exit slits. Figure 2 shows an example at 299.8eV, 300.0eV and 300.2eV with 60 $\mu$ m entrance slit to give  $R=2000$  and 20 $\mu$ m exit slit for diffraction limited imaging (these are the nominal slit widths for 300eV)

The slits and the zone plate will be overfilled typically by a factor of three. Once the beam line is aligned to pass the light the throughput must be stable to about 0.1%.

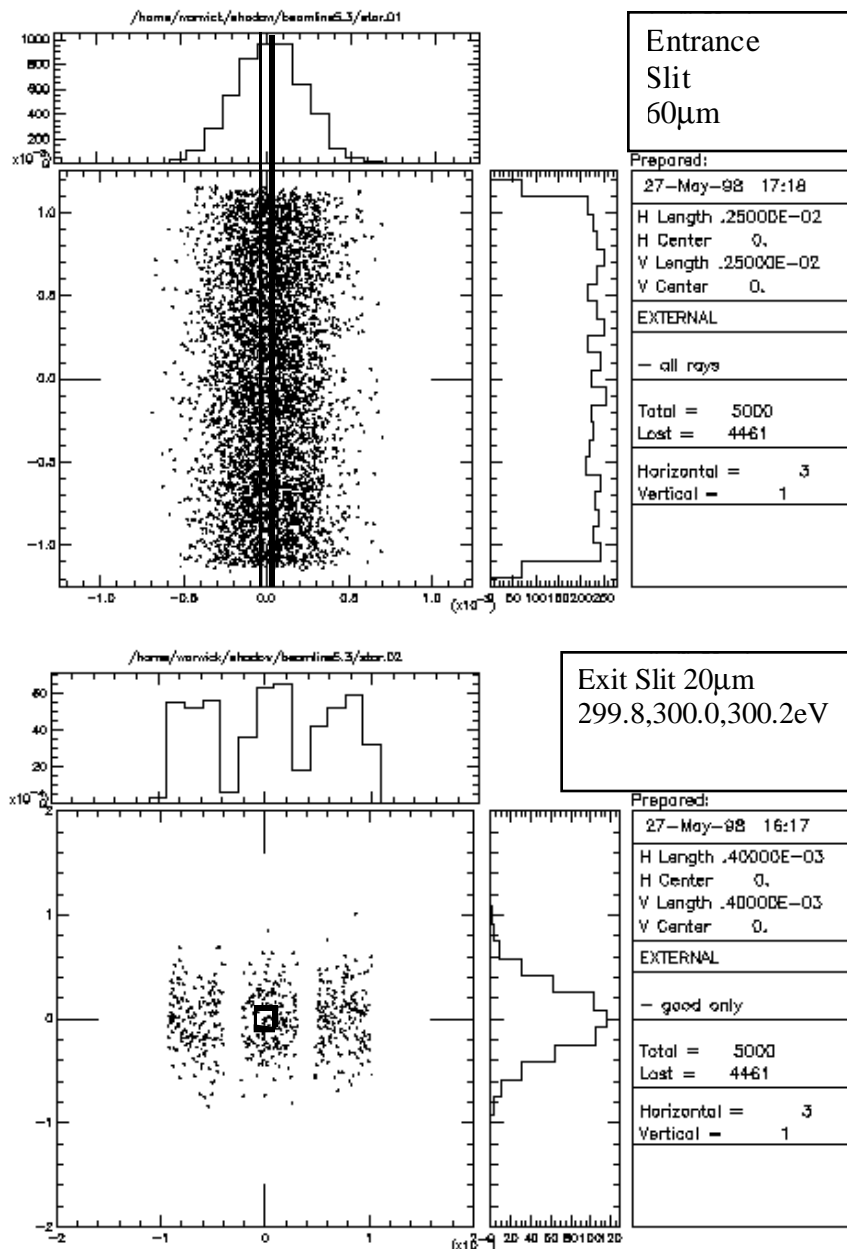


Figure 2. Ray trace analysis of entrance and exit slit overfilling at the nominal settings for 300eV.

## REFERENCES

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